

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

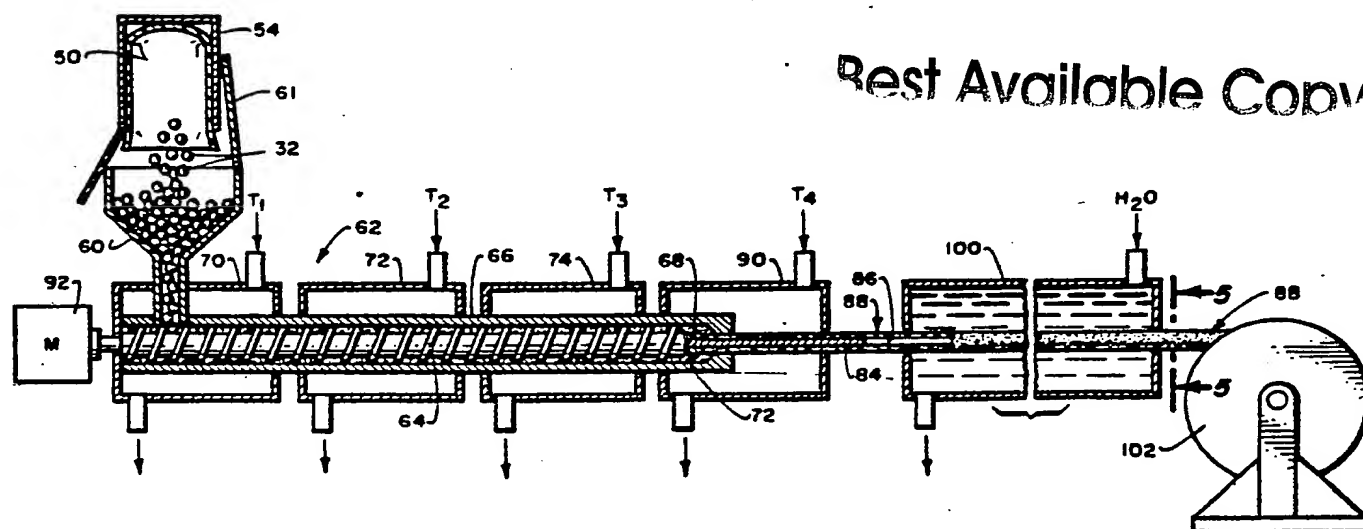
<b>(51) International Patent Classification<sup>4</sup> :</b>  <b>A01G 27/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 85/ 03194</b>  <b>(43) International Publication Date:</b> 1 August 1985 (01.08.85)
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**(21) International Application Number:** PCT/US85/00118  
**(22) International Filing Date:** 22 January 1985 (22.01.85)  
**(31) Priority Application Number:** 573,497  
**(32) Priority Date:** 24 January 1984 (24.01.84)  
**(33) Priority Country:** US  
  
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**(81) Designated States:** AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), LU (European patent), NL (European patent), SE (European patent).

**Published**

*With international search report.  
 Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

Best Available Copy

**(54) Title:** POROUS IRRIGATION PIPE AND METHOD

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**(57) Abstract**

A mixture of crumb rubber, binder, such as polyethylene, and slip contact agent, such as talc, and lubricant, such as a metal stearate, is formed in a blender (10), is shaped into pellets (32) by extruding a strand of the mixture (26) into water (28) and breaking the strand into pellets. The pellets (32) are adjusted to a preselected water content in drier (46) before storage in closed bags (50), stored and reinforced in a container (54). The controlled water content pellets (32) are formed into porous pipe (88) by extrusion in pipe extruder (62) having the feeding, transition and metering zones separately heated to temperatures from 320°F. to 400°F. (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>). The die has a separate jacket (90) receiving heat exchange fluid for heating the die (68) to a temperature from 290°F. to 380°F. to form a porous pipe (88) having more uniform porosity. Porosity is controlled by selecting water content of the pellets and controlling die temperature.

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## Description

## POROUS IRRIGATION PIPE AND METHOD

Technical Field

5 This invention relates to the production of porous irrigation pipes and, more particularly, to an irrigation pipe fabricated by an improved method utilizing a novel precursor material.

Background Art

10 As population steadily increases, water becomes a more important and increasingly scarcer and more expensive resource. Agriculture is one of the most important uses of surface water. It is necessary to develop more efficient systems for delivering water to plants. Surface watering tends  
15 to be wasteful since water that is not absorbed quickly enough runs off or evaporates, and the water that is absorbed must wet the soil until it reaches the roots, the water gathering system for most plants.

20 Surface irrigation systems must be removed and replaced each time the field is tilled or plowed for replanting. Irrigation systems interfere with mechanical harvesting and require substantial maintenance. Above ground watering should usually be  
25 conducted during the day since many plants are subject to decay at night. Furthermore, above-ground watering interferes with usage of recreational areas such as parks, athletic fields and golf courses. Surface watering is non-specific in that the crop and  
30 weeds are both equally watered.

Because of the limitations in above-ground irrigation, subsurface irrigation systems have been developed in which water is directly fed at an optimum subsurface depth to the roots of the crop being

cultivated. The pipe must be inert to the soil environment, must be capable of withstanding hydrostatic pressure in the presence of hard objects such as rocks without collapse and preferably is flexible, so that it does not suffer brittle failure and can be bent to follow crop-line contours.

There are numerous agricultural applications for an irrigation pipe which leaks water slowly over its entire surface and length. Such pipes can be buried underground at levels appropriate for the particular crop being grown, and will supply water directly to the root system. With proper controls, the water level in the soil can be maintained at near-optimum levels. With some crops, this has been shown to increase yields substantially.

A porous irrigation pipe has been produced from reclaimed, tire rubber mixed with a binder such as polyethylene. This mixture is extruded to form the pipe, and the water present within the hot extrudate vaporizes, producing the small pores through which water seeps under pressures of a few psi. While this pipe is useful for some applications, it has several drawbacks for many large-scale agricultural uses. The most important problem with the present product is its highly variable porosity. Some sections had no pores and other sections very large pores. The rate at which water emerges from this product varies by 50 to 75 percent or more within a few feet along its length. If it were used with closely spaced plantings, such as densely packed sugar cane plants, some areas would be overwatered, while others would be essentially dry.

Another problem is that the overall porosity of the pipe is poorly controlled from lot to lot. This causes severe engineering problems when one

tries to design a water system for a particular location. What is normally done is to use many pressure regulators throughout the system. This is expensive and further limits the potential applications of the porous pipe material.

It has been discovered that the wide variation in porosity is due to failure to control the moisture content of the raw materials. The dry powder is somewhat hygroscopic and prior production systems disclosed by Turner in U.S. Patent No. 4,003,408; No. 4,110,420 and No. 4,168,799 relied on absorption of water by the crumb material to provide the blowing or pore forming agent. However, the water content of each batch or portion of a batch varies with humidity, temperature, etc. of the environment. Since the amount of water present in the extrudate is very important to the porosity of the final pipe, variations in the water content of the feed will produce unacceptable variations of the product. Turner attempted to control excess water by venting the extruder but this did not effectively control variations in porosity.

The raw material is a mixture of fine powders and small amounts of oils. Such materials do not feed well in single-screw extruders. Moreover, uneven feeding of the powders will produce variations in the density and thickness in the wall of the pipe. Since these factors are important to the porosity of the wall, uneven feeding in the extruder will result in further inconsistent leak rates.

#### Statement of the Invention

Porous irrigation pipe has been developed in accordance with this invention having extremely consistent porosities along the length of the pipes.

Irrigation systems containing fewer pressure regulators can be deployed. Crop yields will increase since a higher percentage of plants will receive a uniform amount of water. The porous pipe of the invention  
5 will have particular application to underground drip or continuous irrigation of densely packed crops such as sugar cane.

The improved, porous irrigation pipe is made possible by accurate control of the water content  
10 of the raw material and by providing the raw material in a form in which it feeds consistently and reliably to the extruder. The high surface area crumb and powder mixture had water contents varying from about 0.2 percent by weight up to several percent water by  
15 weight and varied throughout the batch. The moisture content of the material of the invention has a moisture content not varying by more than  $\pm 10$  percent throughout the batch and is at a value between 0.5 to 3 percent by weight, preferably from about 0.75  
20 percent by weight to 1.5 percent by weight of water.

The improved pipe is preferably produced in accordance with the invention by preprocessing the raw material into a shaped pellet form. This material feeds very consistently and reliably into a variety  
25 of types of single screw extruders. This makes it possible to produce the porous pipe in virtually any location where standard extrusion equipment is available. This reduces cost of shipping, production and installation of the porous pipe. Additionally,  
30 the moisture content of the pellets can be adjusted to predetermined, specific values depending on the desired porosity and leak rate. The pellets are stored under water-excluding conditions such as in vapor barrier containers. The pellets are much less

hygroscopic than the high surface area powder materials of the prior art.

Another difference in the production methods is that the use of a non-vented extruder becomes possible since water content is known and there is no need to vent excess vapor pressure. Since the parameters of water content and feed rate are controlled and the temperature is controllable, porosity can be controlled by preselection of water content of the pellets. Alternately, since all variables are controlled, porosity of a batch or run can be controlled by changing the temperatures in the extruder and die.

Another novel feature of the invention is the provision of pelletizable formulations. The powder materials previously utilized are not capable of being pelletized. The pellet form of feed containing controlled moisture content and pelletizing additives makes possible continuous production in high volume of porous irrigation pipe with very consistent leak rates on a variety of extruders anywhere in the world where the pipe is needed. The porous pipe can be optimized for porosity, size and strength for the intended application. In addition to the savings in shipping and production, the porous pipe of the invention produces irrigation systems which in many cases will yield substantial increases in crop yields due to more accurate watering cycles.

These and many other features and attendant advantages of the invention will become apparent as the invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings.

### Brief Description of the Drawings

Figure 1 is a schematic view of a train of equipment for producing pellets in accordance with the invention;

5        Figure 2 is an enlarged view in elevation of a pellet;

Figure 3 is a partially broken-away view in elevation of a humidity-controlled storage container;

Figure 4 is a schematic view of a system for  
10        extruding porous pipe in accordance with the invention; and

Figure 5 is a view in section taken along line 5-5 of Figure 4.

### Detailed Description of the Invention

15        The pelletizable mixture of the invention includes a major portion of elastomer in crumb form, a minor amount, usually from 1.0 to 6.0 phr of a slip agent, preferably a mineral such as talc and 0.1 to 1.0 phr of a lubricant, such as a metal stearate.

20        The elastomer can be natural rubber which is cis-1,4-polyisoprene or synthetic homopolymers of butadiene or isoprene or their copolymers with minor amounts of 0.1 to 20 percent by weight of vinyl monomers such as styrene, isobutylene or acrylonitrile.

25        It is preferred that the elastomer be vulcanized. A ready and inexpensive source of prevulcanized crumb rubber is available as rubber reclaimed from automobile tires after removal of the metal tire cords and metal reinforcement in the head. The rubber is  
30        ground into crumb particles no larger than those passing through a 10 mesh screen, preferably from 20 mesh to 60 mesh.

The binder resin is a thermoplastic material





capable of softening at a temperature below 300°F so that pores will form during extrusion. The resin must be stable to longterm exposure to soil environment and to fertilizers, herbicides or pesticides seeping into the adjacent soil or to fertilizers, growth regulators herbicides or pesticides dispensed by dissolving in the irrigation water. The resin must be inert to the other components of the pipe such as the crumb rubber under extrusion conditions.

5

10 Polyvinyl acetate is excluded from use since it will react with the crumb rubber. Styrene polymers including impact polystyrene copolymers are useful as are linear polyamides such as various Nylons, polyvinyl-chloride, polyphenylene oxide and polyphenylene sulfide polymers.

15

The most preferred group of polymers are the linear polymers of alkenes of 2 to 4 carbon atoms such as polyethylene, polypropylene or polybutene. These polymers are unreactive in soil and in the extrusion barrel and have long segments of linearity providing crystalline behavior. Polyethylenes have lower melting temperatures, are tougher and hold shape better. High density polyethylenes have densities from about 0.94 to about 0.97 gm/cc, and porous pipe prepared with all high density polyethylene binder are somewhat stiff, brittle and difficult to extrude.

20

25 Low density polyethylenes have densities from about 0.90 to 0.93 gm/cc, and porous pipe prepared with all low density polyethylene binder are very flexible and can readily be bent to follow a desired path and are readily extruded. These pipes are very useful for above-ground irrigation. However, wall stiffness may not be adequate for subsurface systems. The pipe develops kinks in the bends and does not hold its

30

35 shape. The optimum binder which provides a porous

-8-

pipe which holds its shape without brittleness yet has adequate flexibility is composed of 50 percent to 80 percent by weight of high density polyethylene, preferably 60 percent to 70 percent to 20 percent to 50 percent by weight of low density polyethylene, preferably 30 percent to 40 percent. The polyethylene can be used in any commercial form such as powder, flake or pellets. Reclaimed polyethylene materials can also be used. The form and color of such materials have little effect upon the product.

The slip agent aids in extruding the rubber binder mixture. Finely divided minerals other than talc can be utilized such as clays, silicas, carbonates, or micas. The metal stearate lubricant can be selected from calcium, magnesium or zinc stearates.

Referring now to Figures 1-3, the crumb rubber, additives and binder are thoroughly dry blended in blender 10 such as a ribbon blender or other suitable mixing device to form material which is fed to the hopper 12 of the extruder 14. The mixture is pelletized by being extruded into a die-face pelletizing system. An extruder feeding directly into an underwater or water-ring pelletizer 16 is illustrated. A turn-screw extruder is preferred though a single-screw extruder equipped with a good crammer can be utilized. Strand pelletizers do not work well with the rubber-binder composition of the invention. The extruder is maintained at a temperature of from 320°F to 400°F and the die at a temperature from 250°F to 325°F by means of separate heating systems such as a set of heating jackets 18, 20 receiving separate flows of heated exchange fluids. The extruded strand material should have a bulk density after drying of at least 0.25 gm/cc and has a diameter from 3 to 20 mm, preferably 4 to 10 mm. The strand is broken into

lengths of 3 to 20 mm by means of a mechanical knife 22 immersed in the water bath 24. The water in the bath is cool, usually from 20°F to 80°F and as the extruded strand 26 enters the water 28, it congeals and sets so that a thin blast of air from nozzle 30 breaks the strand 26 into pellets 32 which fall into the collector portion 34 of the water bath 24. The nozzle 30 is connected to an air supply 36 which is pulsed by a controller 38.

10 The dispersion of pellets in water is fed from water bath 24 into a separator such as a cyclone separator 40. The water is recycled to the bath 24 through line 42 while the pellets 32 are delivered by conveyor belt 44 to a dehumidifying drier 46 to  
15 dry the pellets to a preselected moisture content between 0.5 to 2.5% by weight depending on the porosity desired. The conveyor belt 44 carries the dried pellets 32 into a closed hopper 48 having a humidity controlled atmosphere which feeds the  
20 pellets into a storage container such as a polyethylene bag 50. The bag is closed with a secure closure such as a band 52 of metal and can be placed in an outer protective container such as a box or a barrel 54. The dried pellets contain a uniform  
25 moisture content which can be accurately controlled and the moisture content is stable for extended periods. The pellets have a much smaller surface area than the prior powder materials and are humidity stable without storage for short periods  
30 of time.

Referring now to Figure 4, the pellets 32 are fed to hopper 60 of a pipe extruder 62. The hopper has a lid 61 to isolate the feed from the environment. The extruder preferably contains a

single low pressure screw 64 and has a length to diameter ratio of at least 24/1, preferably at least 35/1. The compression ratio of the feeding section to the metering section can be from 1.5/1 to 2.2/1. The diameter of the barrel 66 is suitable to produce pipes having outside diameters from 2 to 10 inches, usually from 3 to 6 inches. Mixing pins are to be avoided since the crumb rubber can foul these elements.

10           The process is operated at a temperature high enough to melt the binder resin but below the melting temperature of the elastomer. Good temperature control of the barrel and especially of the die 68 is required usually to within  $\pm 5^{\circ}\text{F}$ . A more uniform porous pipe  
15 is prepared by providing an increasing temperature profile over the length of extruder 62. Separate heating jackets 70, 72, 74 can surround the feeding, transition and metering sections, respectively, of the extruder barrel 66. Each jacket receives a separate  
20 flow of heat exchange fluid. The feeding section can be heated to  $340^{\circ}\text{F} - 360^{\circ}\text{F}$  ( $T_1$ ), the transition section from  $360^{\circ}\text{F} - 370^{\circ}\text{F}$  ( $T_2$ ), and the metering section from  $365^{\circ}\text{F}$  to  $375^{\circ}\text{F}$  ( $T_3$ ).

          The die 80 is also provided with a separate  
25 temperature control. A suitable die is shown in Figure 5 of U.S. Patent No. 4,168,799. The die contains an outlet orifice 72 in front of which is mounted a mandrel 84 for forming the bore 86 of the porous pipe 88. The mandrel may be removable to  
30 vary the wall thickness of the pipe. The thickness is selected depending on desired flow rate, leak rate and wall strength to avoid collapse. Wall thickness is usually from 0.1 to 2.0 inches. In U.S. Patent 4,168,799, the die is chilled to a temperature

of from 40°F to 80°F in order to avoid forming an impermeable skin on the surface of the pipe, and the barrel is vented to remove excess pressure. However, in accordance with the present invention, the barrel need not be vented and the die is heated to a preselected temperature from 240°F to 300°F to control porosity of the porous pipe. An annular jacket 90 receives a flow of preheated heat exchange fluid ( $T_4$ ).

As the screw 64 is rotated by motor 92, the feed moves forwardly and the binder resin melts. The water vaporizes and the expanding bubbles of steam form a network of pores 96 extending from the bore 86 to the surface 98 of the porous pipe. The pipe 88 can be extruded through the die 68 into the ambient and enters a chilling bath 100 containing water at a temperature of about 25°F to 50°F before being pulled onto rewind stand 102. The chiller bath usually has a length of at least 40 feet.

The invention will now be illustrated by the following specific examples of practice.

The dry materials were mixed in a ribbon blender and fed into the hopper of a twin-screw extruder heated to 360°F - 390°F with a 5 mm die heated to 300°F. The water bath was maintained at 35°F - 40°F and the 5 mm strand was chopped into approximately ground pellets about 8 - 9 mm in diameter by an air knife. After drying the pellets had a density of 0.275 gm/ml.

#### Example 1

The following mixture was pelletized and dried to 0.75 percent moisture content:

Crumbed Tire Rubber (48 Mesh)	100 lb.
Low Density Polyethylene	35 lb.
Finely Powdered Talc	3 lb.
Zinc Stearate	.25 lb.

- 5 These pellets were extruded in an unvented single screw extruder into porous pipe with an ID of 0.55 inch and a wall thickness of 0.2 inch. The extruder temperatures were:

	Extruder (all zones)	350°F.
10	Gate	340°F.
	Spider	335°F.
	Die	335°F.

This porous pipe had the following porosities at 10 psi:

- 15           0.27 $\pm$ .02 GPM/100 Linear Feet  
            0.11 $\pm$ .003 GPM/100 Square Feet

#### Example 2

- This same pelletized raw material of Example 1 was extruded under the same conditions, except that 20 the die temperature was 290°F. This pipe had the following porosities at 10 psi.

0.19 $\pm$ 0.17 GPM/100 Linear Feet  
0.076 $\pm$ 0.007 GPM/100 Square Feet

#### Example 3

- 25           Example 1 was repeated except that 35 lb. of high density polyethylene was substituted for the low density polyethylene binder. The pellets were more difficult to extrude and the pipe was more brittle and less flexible.

## Example 4

	Crumbed Tire Rubber (40 Mesh)	100 lb.
	High Density Polyethylene	25 lb.
	Low Density Polyethylene	10 lb.
	Slip Agent-Talc	3 lb.
5	Lubricant-Calcium Stearate	0.25 lb.

The formulation was processed into pellets and dried to contain 1.0 percent moisture. The pellets were extruded in a 2.5 inch diameter, 24/1 L/D, Prodex single-screw extruder. The extruder was equipped with a PVC type screw, which had a compression ratio of 1.9/1, and a circular pipe die with a land-length of 16/1. Temperatures in the extruder were maintained at 340°F - 360°F. The gate, spider and die temperatures were adjusted to yield an extrudate having the temperatures shown below. Porous pipes having a wall thickness of 0.165 inch were produced having the following properties:

Extrudate Temperature (°F.)	<u>APPROXIMATE LEAK RATE</u>		
	GPM/100 sq ft	GPM/100 linear feet	
		0.5" ID Pipe	1.0" ID Pipe
250-260	0.10±0.02	0.25±0.04	0.50±0.08
275-285	0.20±0.03	0.50±0.08	1.00±0.16
300-320	0.40±0.06	1.00±0.16	2.00±0.32
340-360	0.80±0.12	2.00±0.32	4.00±0.64

The pellet material fed smoothly and the porous pipe had good compression strength, yet was flexible. The pipe had uniform porosity along its length. The consistency of leak rate is measured by determining the amount of flow of one foot increments over 50 feet of pipe to determine the consistency factor, Cv, --the standard deviation/ flow rate.

For most prior commercial porous pipes, the

Cv achievable is from 0.25 to 0.5. For most applications, a Cv of 0.2 is preferred and for densely packed plants such as sugar cane, a Cv of 0.1 is necessary to reduce no-growth in overwet or dry areas of irrigation.

5 A one-half inch I.D. porous pipe produced in accordance with the invention having a flow rate of 1 gpm/100 linear feet at 10 psi pressure has a Cv of 0.1 to 0.15 and a porous pipe having a flow rate of 10 0.25 gpm/100 linear feet has a measured Cv of 0.05 to 0.1.

It is to be realized that only preferred embodiments of the invention have been described and that numerous substitutions, modifications and alterations 15 are permissible without departing from the spirit and scope of the invention as defined in the following claims.



## CLAIMS

1. An extrudable composition comprising:  
100 parts by weight of particulate elastomer;  
5 10 to 60 phr of a thermoplastic binder;  
1.0 to 6.0 phr of a slip agent; and  
0.1 to 1.0 phr of a lubricant.
2. A composition according to claim 1 in which the elastomer is vulcanized rubber.
- 10 3. A composition according to claim 2 in which the elastomer is reclaimed rubber in crumb form having a size from 10 to 60 mesh.
4. A composition according to claim 3 in which the binder has a melting temperature below 300°F.
- 15 5. A composition according to claim 4 in which the binder resin is a linear polyethylene.
6. A composition according to claim 5 in which the resin is a mixture of 50 percent to 80 percent by weight of high density polyethylene and 20 percent  
20 to 50 percent by weight of low density polyethylene.
7. A composition according to claim 4 in which the slip agent is a finely divided mineral and the lubricant is a metal stearate.
8. A composition according to claim 7 in which  
25 the slip agent is a talc and the metal stearate is selected from calcium, magnesium or zinc stearates.

9. A composition according to claim 2 in which the moisture content is from 0.5 to 3 percent by weight.
10. A composition according to claim 9 in which the moisture content of a batch does not vary by more than +10 percent.
11. A composition according to claim 9 in the form of a pellet having a bulk density of at least 0.25 gm/cc.
- 10 12. A composition according to claim 11 in which the pellet has a diameter from about 3 to 20 mm.
13. A porous pipe extruded from the composition of claim 1.
14. A porous pipe according to claim 13 having  
15 a diameter from 2 to 10 inches.
15. A porous pipe according to claim 14 in which the pipe has a wall thickness from 0.1 to 2.0 inches.
16. A method of forming lengths of porous pipe comprising the steps of:
- 20 adjusting the moisture content to a value between 0.5 to 3.0 percent of a mixture comprising:  
100 parts by weight of a particulate elastomer;
- 25 10 to 60 phr of a thermoplastic resin;  
1.0 to 6.0 phr of a slip agent; and  
0.1 to 1.0 phr of a lubricant;
- extruding the composition in a pipe extruder at a temperature of from 320°F. to 400°F. to

form a pipe; and  
cooling the pipe.

17. A method according to claim 16 in which the die is separately heated to a predetermined temperature from 240°F. to 380°F.

18. A method according to claim 17 in which the barrel of the extruder is not vented.

19. A method of forming an extrudable composition comprising the steps of:

10 forming a mixture of:

100 parts by weight of particulate elastomer;

10 to 60 phr of a thermoplastic binder;

1.0 to 6.0 phr of a slip agent; and

15 0.1 to 1.0 phr of a lubricant;

pelletizing the mixture; and

adjusting the moisture content of the pellets to a value between 0.5 percent to 3.0 percent by weight.

20 20. A method according to claim 19 in which the pellets are formed by extruding the mixture as a strand into chilled water and breaking the strands into pellets.

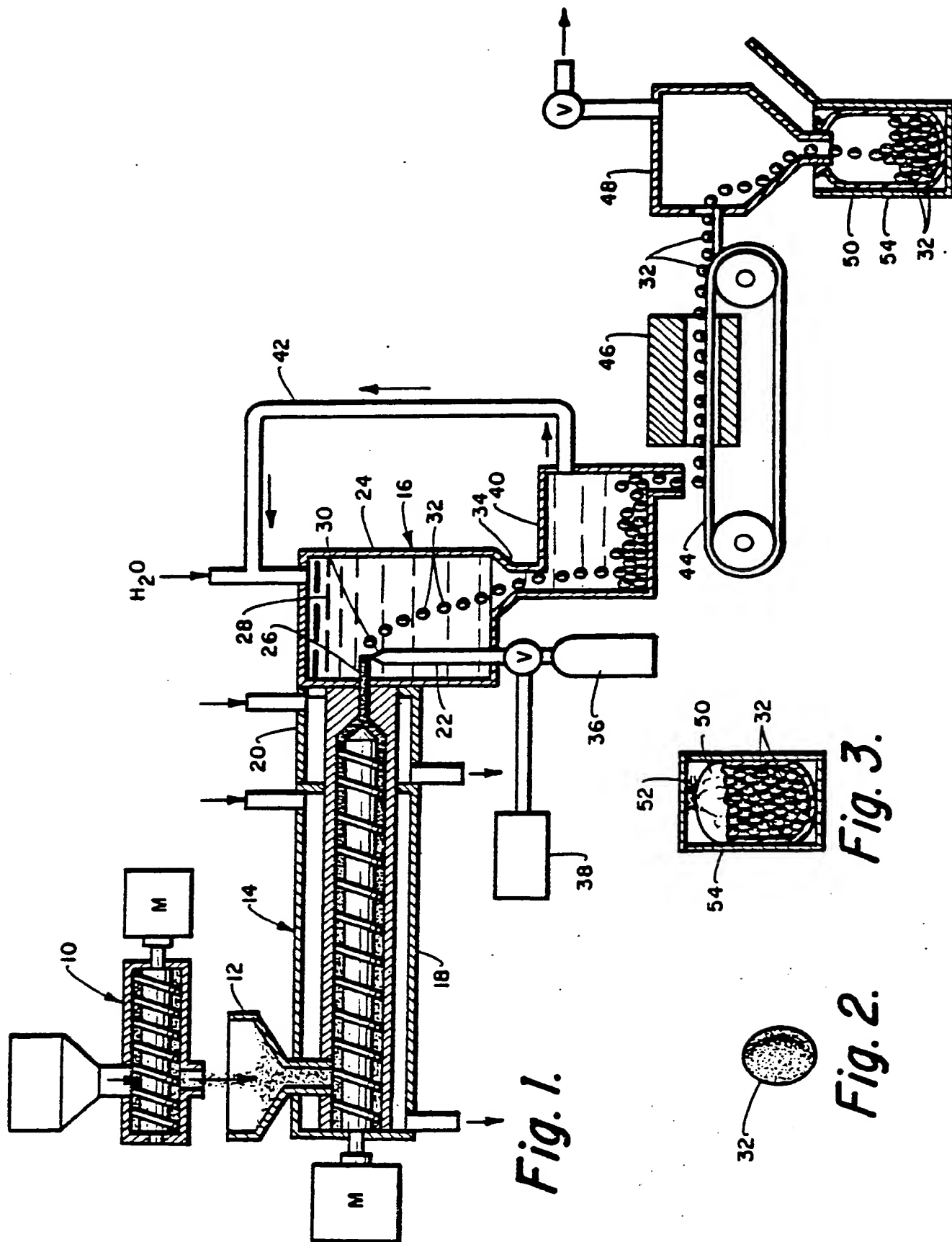


Fig. 1.

Fig. 2.

Fig. 3.

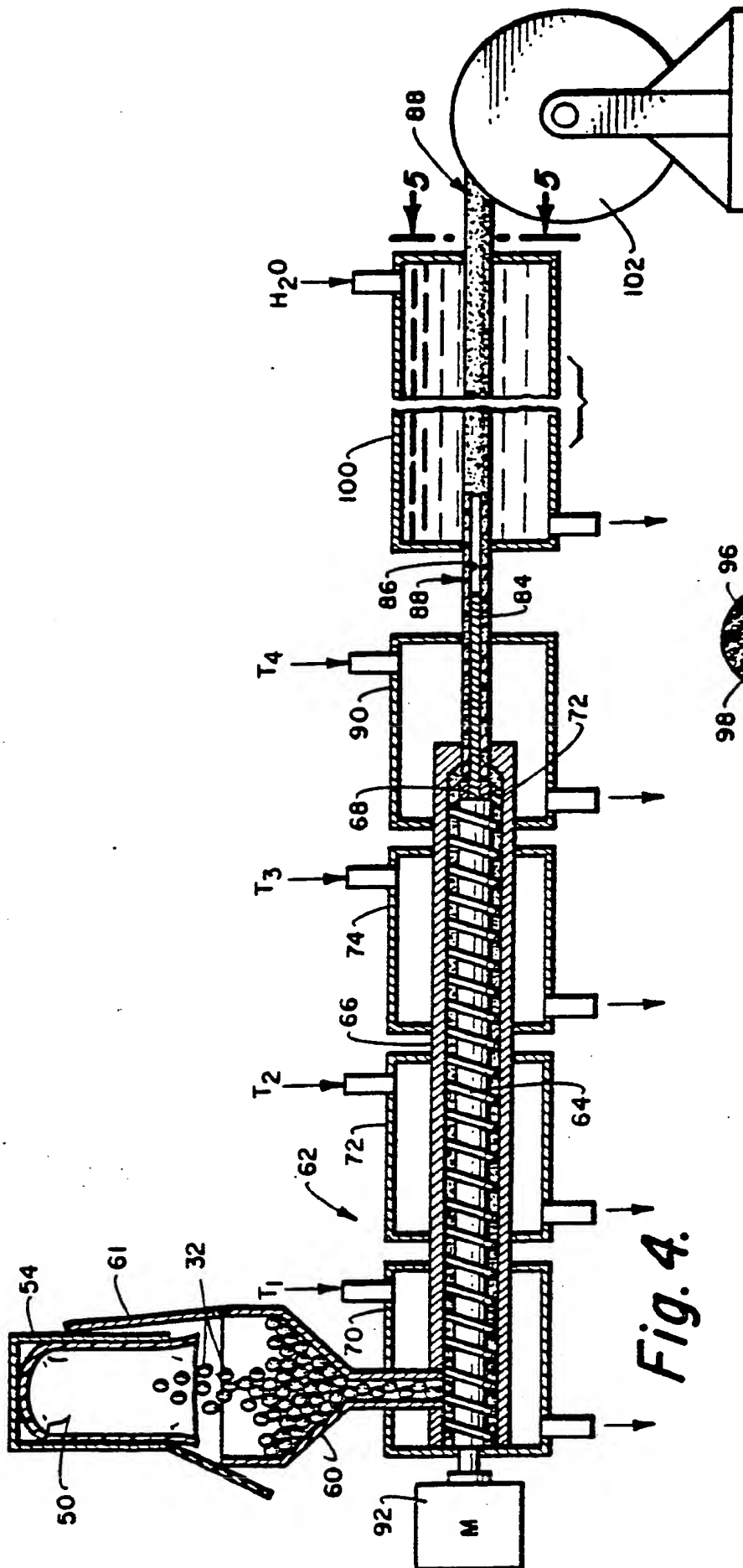


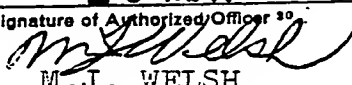
Fig. 4.



Fig. 5.

# INTERNATIONAL SEARCH REPORT

International Application No PCT/US85/00118

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>3</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
INT. CL. <sup>84</sup> A01G 27/00		
U.S. CL. 521/81		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>4</sup>		
Classification System	Classification Symbols	
U.S.	264/41, 45.9, 53, 109, 122, 123; 521/81, 91, 93, 140; 524/399, 400, 451; 525/197, 198, 232	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>5</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup>		
Category <sup>6</sup>	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
X	US, A, 4,168,799 PUBLISHED 25 SEPTEMBER 1979 TURNER	1-20
X	US, A, 4,397,916 PUBLISHED 09 AUGUST 1983 NAGANO	1-20
X	US, A, 4,391,767 PUBLISHED 05 JULY 1983 PEARS	1-20
X	US, A, 4,003,408 PUBLISHED 18 JANUARY 1977 TURNER	1-20
X	US, A, 4,110,420 PUBLISHED 29 AUGUST 1978 TURNER	1-20
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<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search <sup>2</sup>	Date of Mailing of this International Search Report <sup>1</sup>	
16 MAY 1985	29 MAY 1985	
International Searching Authority <sup>1</sup>	Signature of Authorized Officer <sup>10</sup>	
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